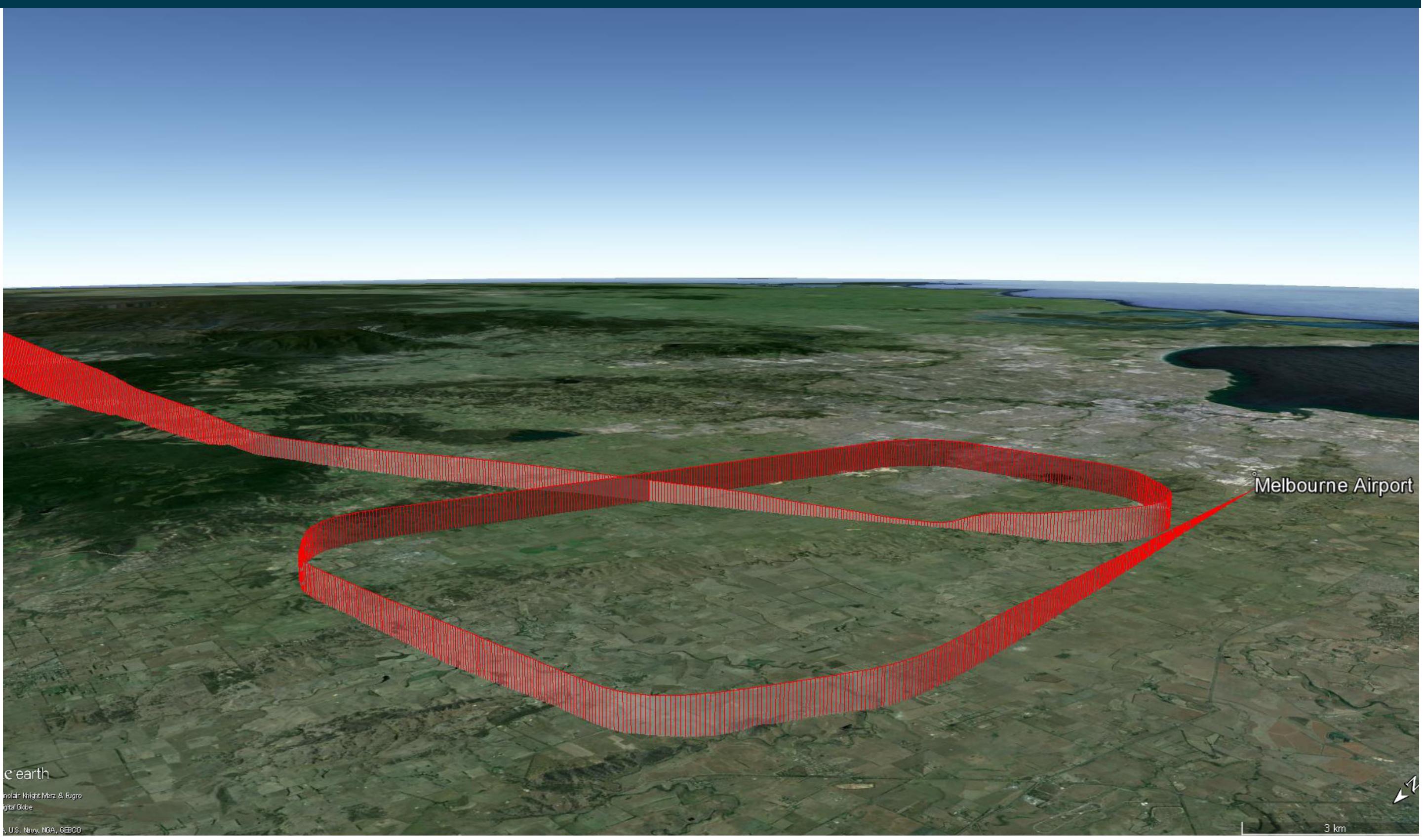
Australian Government
Australian Transport Safety Bureau

Flight path management and ground proximity warning involving Airbus A330-202 VH-EBV

15 km NNE of Melbourne Airport, Victoria, | 8 March 2013



Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation
AO-2013-047
Final – 9 July 2015

Front cover: Google Earth©

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Publishing information

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Addendum

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Safety summary

What happened

On 8 March 2013, the flight crew of a Qantas Airways Limited (Qantas) A330 aircraft, registered VH-EBV, was conducting a visual approach to Melbourne Airport, Victoria. The captain was the pilot flying with autopilot engaged.

Soon after being cleared for the approach, on descent through 3,000 ft, the captain set an altitude target of 1,000 ft in the auto-flight system and selected the landing gear down, the first stage of wing flap and 180 kt as the target speed. The descent was continued in auto-flight open descent mode and reached a maximum of 2,200 ft/min. As the aircraft was descending through about 1,800 ft the first officer advised the captain that they were low. The captain reduced the rate of descent by selecting auto-flight vertical speed mode but a short time later the enhanced ground proximity warning system (EGPWS) provided 'TERRAIN' alerts followed by 'PULL UP' warnings. The crew carried out an EGPWS recovery manoeuvre and subsequently landed via an instrument approach.

At the time of the EGPWS alert the aircraft had descended to 1,400 ft, which in that area was 600 ft above ground level, with 9 NM (17 km) to run to touchdown. This was 100 ft below the control area lower limit and 1,900 ft below a normal 3° descent profile.

What the ATSB found

The ATSB found that during the visual approach the captain's performance capability was probably reduced due to the combined effects of disrupted and restricted sleep, a limited recent food intake and a cold/virus. The captain assessed the aircraft's flight path using glide slope indications that were not valid. This resulted in an incorrect assessment that the aircraft was above the nominal descent profile.

In addition, the combination of the selection of an ineffective altitude target while using the auto-flight open descent mode and ineffective monitoring of the aircraft's flight path resulted in a significant deviation below the nominal descent profile. The flight crew's action in reducing the aircraft's rate of descent following their comprehension of the altitude deviation did not prevent the aircraft descending outside controlled airspace and the activation of the EGPWS.

The ATSB also identified that limited guidance was provided by Qantas on the conduct of a visual approach and the associated briefing required to ensure flight crew had a shared understanding of the intended approach.

What's been done as a result

In response to this occurrence Qantas updated their training material for visual approaches and enhanced similar material in their captain/first officer conversion/promotion training books. In addition, targeted questions were developed that required check pilot sign-off for proficiency. Finally, visual approaches were included as a discussion subject during flight crew route checks for the period 2013–2015.

Safety message

The ATSB reminds operators and flight crew of the importance of continuous attention to the appropriateness of the auto-flight system modes in use. Equally, the ATSB stresses the importance of continually monitoring descent profiles, irrespective of the type of approach being flown and the level of automation being used. For flight crew, this occurrence illustrates the need to communicate their intentions and actions to ensure a shared understanding of the intended approach.

Contents

The occurrence

On 8 March 2013, a Qantas Airways Limited (Qantas) flight crew was rostered to operate an Airbus A330 aircraft, registered VH-EBV, on a scheduled passenger flight from Perth, Western Australia to Sydney, New South Wales, and then to Melbourne, Victoria followed by a return sector to Sydney. These flights were scheduled on the fifth day of a 5-day duty roster pattern for the crew.

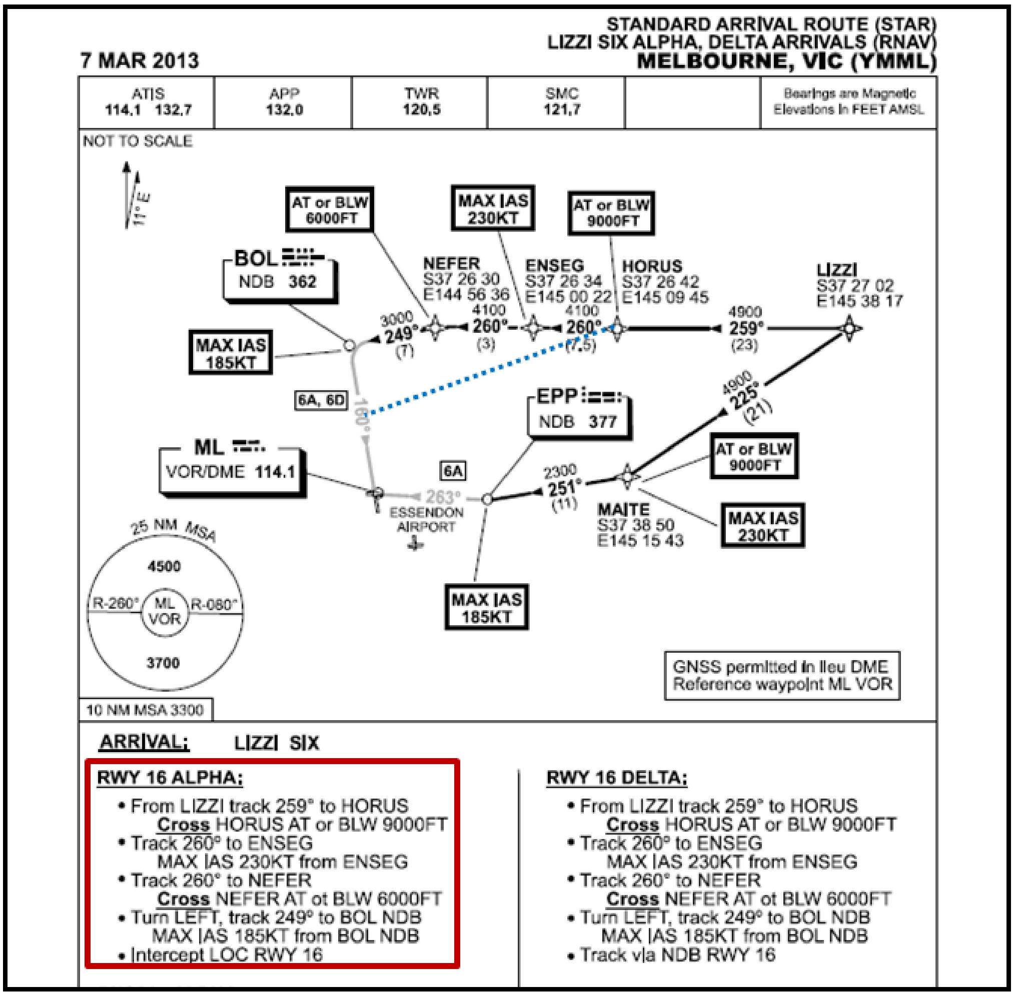
Following a rest period in Perth of about 31 hours, the flight crew reported for duty at 0805 Western Standard Time[1]. The crew reported being adequately rested but the captain recalled having had an interrupted sleep, waking at about 0500 with a throat irritation that worsened as the day progressed.

The flight to Sydney proceeded without incident and arrived a few minutes ahead of schedule. After being on the ground for 1 hour and 17 minutes, the crew departed for Melbourne at 1733 Eastern Daylight-saving Time[2]. The captain was the pilot flying.

Prior to top of descent, air traffic control (ATC) cleared the crew to track via the LIZZI SIX ALPHA standard arrival route (STAR) for a landing on runway 16 (Figure 1). The crew programmed the STAR as the active flight plan in the aircraft's auto-flight system. However, based on their previous experience operating into Melbourne Airport, and in anticipation of possible track shortening, they also programmed a secondary flight plan that would track the aircraft from waypoint HORUS to intercept the runway centre-line at the final approach fix (FAF), about 6 NM (11 km) from touchdown (Figures 1 and 2). The crew conducted an arrival briefing that included the potential track shortening, and relevant speed and airspace restrictions.

1 Western Standard Time was Coordinated Universal Time + 8 hours.
2 Eastern Daylight-saving Time (EDT) was Coordinated Universal Time (UTC) + 11 hours. Unless otherwise annotated, all remaining times are in EDT.

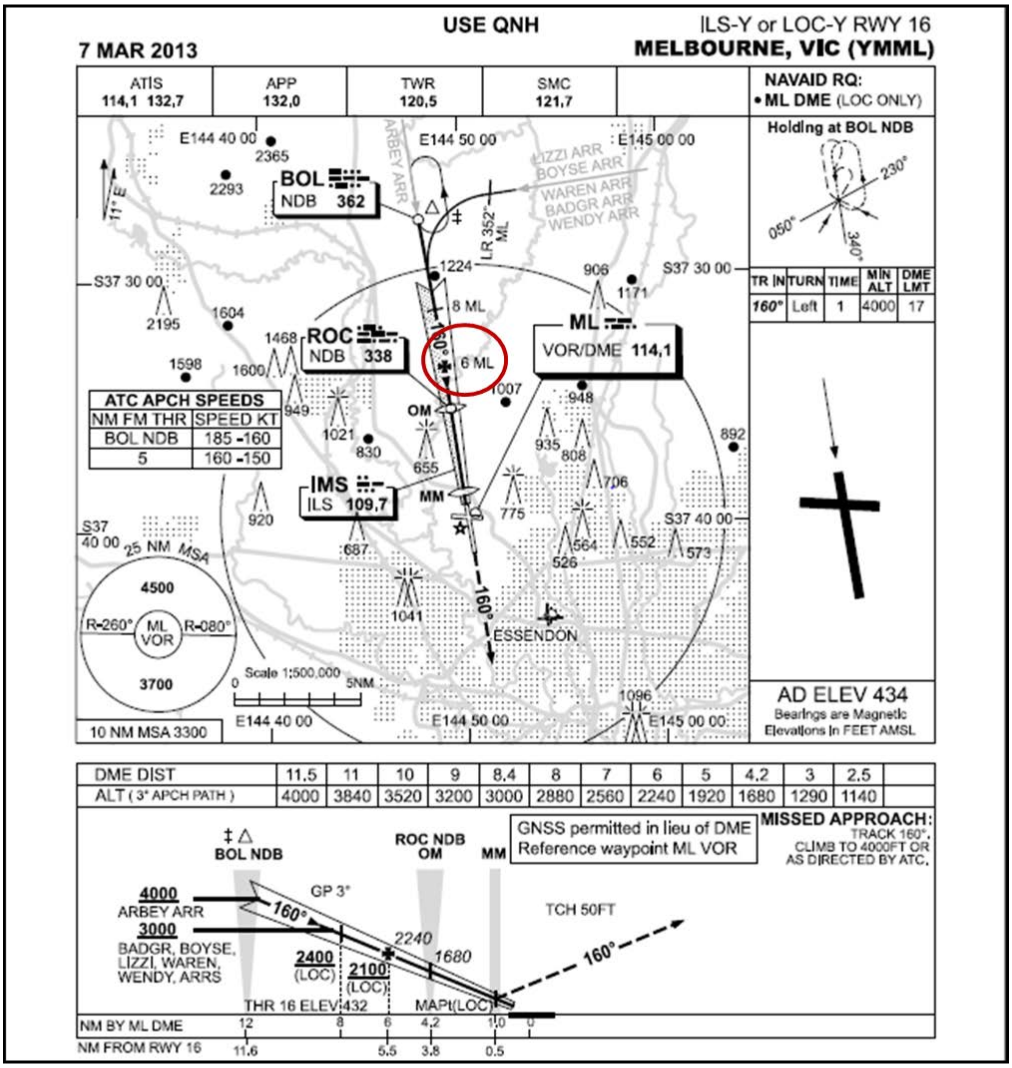
Figure 1: LIZZI SIX STAR chart with anticipated track shortening (blue dotted line)



Source: Airservices Australia (edited by the ATSB)

As the crew were about to commence descent, ATC cancelled all speed restrictions, requested a high-speed descent, and advised the crew to expect track shortening. Following their acceptance of the high-speed descent request, the crew amended the programmed descent speeds and commenced descent with the auto-flight system in managed mode. In this mode the aircraft followed a pre-computed profile that allowed for aircraft deceleration and airspace restrictions along the active flight plan route.

Figure 2: Melbourne instrument landing system chart showing the location of the final approach fix (circled)



Source: Airservices Australia (edited by the ATSB)

At 1844, with the aircraft approaching 9,000 ft, ATC cleared the crew to descend to 5,000 ft and offered track shortening from HORUS (Figure 1). The crew accepted an amended track from HORUS to the FAF and activated the secondary flight plan.

The amended tracking reduced the remaining track miles to touchdown by about 5 NM (9 km). The captain recalled that after activating the secondary flight plan, the aircraft was about 1,400 ft above the re-computed profile. In response to his understanding of the aircraft's position, the captain increased the rate of descent by selecting auto-flight open descent mode and deploying half speed brake. The use of that mode, in combination with speed brake, increased the aircraft's rate of descent to a recorded maximum of 4,000 ft/min, while maintaining the pre-programmed airspeed.

At about 1847, ATC cleared the crew to descend to 4,100 ft and asked them to report when visual. It was about 90 minutes before last light[3] and the crew could see the ground and runway but the captain stated that visibility was affected by sun glare and terrain shadowing (due to mid-level

[3] Last light is the time when the centre of the sun is at an angle of 6° below the horizon following sunset. At this time large objects are not definable but may be seen and the brightest stars are visible under clear atmospheric conditions. Last light can also be referred to as the end of evening civil twilight.

scattered cloud[4]). The crew reported visual to ATC and were cleared to descend slightly lower to 4,000 ft.

About 1 minute later, as the aircraft was approaching 4,000 ft, the auto-flight system vertical mode automatically changed from open descent to altitude capture and then to altitude hold.[5] The aircraft was now 17 NM (31 km) from touchdown with a reducing airspeed of 200 kt about 2,000 ft below a nominal 3° descent profile and 1,500 ft above the lower limit of controlled airspace. ATC cleared the crew to continue descent to 3,000 ft and the captain reselected open descent mode. The captain then instructed the first officer to activate the approach phase in the auto-flight system to enable continued deceleration towards the final approach speed.

At 1848:21, ATC asked the crew if they could accept an additional 2 NM (4 km) of track shortening direct to the Rockdale non-directional beacon (Figure 2). The crew declined that request.

At 1848:55, ATC requested the crew to maintain an airspeed of 180 kt until turning final. The crew responded that they would endeavour to comply but advised that they would need to slow the aircraft down prior to the FAF. ATC then cleared the crew to make a visual approach, effectively allowing them to descend as required in accordance with the published visual approach procedures (see the section titled *Air traffic control procedures*). The aircraft was now approaching 3,000 ft and the auto-flight system was in the process of capturing that altitude. At that time the aircraft was 14 NM (26 km) from touchdown, on a bearing displaced 45° from the extended runway centre-line, 800 ft above the lower limit of controlled airspace and about 1,800 ft below the operator-recommended nominal 3° descent profile (see the section titled *Operator procedures*).

The captain set an altitude target of 1,000 ft in the flight control unit and reselected open descent mode at 1849:36. The first officer reported not hearing the captain verbalise these changes and was unaware that the altitude selector had been changed. By 1850 the crew had selected the landing gear down, the first stage of wing flap and 180 kt as the ATC-requested target speed. The descent rate increased to about 2,000 ft/min and exceeded the maximum stipulated by Qantas for a brief period.

The captain reported observing the aircraft's instrument landing system (ILS)[6] glide slope deviation indicator on the primary flight display and that it was indicating the aircraft was above the glide slope. This appeared valid to the captain and was consistent with his earlier assessment of the aircraft being high relative to the track-shortened computed profile. Although other information about the aircraft's flight path was available and the aircraft was not established on the ILS localiser, the captain used the glide slope deviation indicator as the primary vertical flight path guidance.

The first officer reported completing various cockpit tasks and monitoring key parameters such as track miles to run, rate of descent, speed brake use and auto-flight mode during the descent. The first officer also reported monitoring the aircraft's flight path by visual reference to the ground. From the first officer's perspective, the approach was proceeding normally until ascertaining from the outside view that the aircraft was too low. The first officer reported checking the primary flight display noting that the aircraft profile deviation indicator confirmed the below-profile state.

This prompted the first officer to advise the captain 'You are low', or words to that effect. In response, at 1850:30, the captain selected auto-flight vertical speed mode and adjusted the vertical speed to reduce the rate of descent to about 500 ft/min. Eight seconds later, an enhanced ground proximity warning system (EGPWS) 'TERRAIN' alert activated when the aircraft was about

[4] Cloud cover is normally reported using expressions that denote the extent of the cover. The expression scattered indicates that cloud was covering between a quarter and a half of the sky.

[5] The recorded flight data is represented at appendix A.

[6] A standard ground aid to landing, comprising two directional radio transmitters: the localiser, which provides direction in the horizontal plane; and the glideslope, for vertical plane direction, usually at an inclination of 3°. Distance measuring equipment or marker beacons along the approach provide distance information.

600 ft above ground level (AGL), followed by a second terrain alert. The aircraft was 9 NM (17 km) from touchdown, on a bearing displaced 30° from the runway centre-line and at an altitude of 1,400 ft at that time. This was 1,900 ft below the nominal 3° descent profile and 100 ft below the lower limit of controlled airspace.

Seconds later the EGPWS generated 'PULL UP' aural warnings. Despite the day-visual conditions the captain decided to conduct the full EGPWS recovery manoeuvre, including disconnecting the auto-flight system, applying full back stick and selecting take-off/go-around thrust. The aircraft climbed rapidly and the warning ceased. After the crew completed the recovery manoeuvre and levelled the aircraft at 4,000 ft, ATC vectored the aircraft for a runway 16 ILS approach. The subsequent approach and landing were normal.

Context

Flight crew information

The captain

The captain held an Air Transport Pilot (Aeroplane) Licence, a multi-engine command instrument rating and a Class 1 Aviation Medical Certificate. The captain had a total of 21,907 hours of aeronautical experience, of which 2,272 hours were on the A330.

In the previous 90 days the captain had completed 139 hours. The captain's most recent simulator check was on 23 February 2013.

The captain reported having a slightly sore throat in the morning that became worse during the day, particularly during the occurrence flight, and experiencing further cold symptoms following the occurrence. In addition, the captain indicated not feeling like eating, and he did not eat breakfast or lunch that day. A cup of coffee and tea were reported consumed on the trip from Perth to Sydney and a half-cup of soup on the flight from Sydney to Melbourne. The captain reported feeling tired prior to commencing duty on 8 March but self-assessed being fit for duty.

The first officer

The first officer held an Air Transport Pilot (Aeroplane) Licence, a multi-engine command instrument rating and a Class 1 Aviation Medical Certificate. The first officer had a total of 10,027 hours of aeronautical experience, of which 983 hours were on the A330.

In the previous 90 days the first officer had completed 131 hours. The first officer's most recent simulator check was completed on 10 January 2013.

The first officer reported normally obtaining 8 hours sleep each night and obtaining good sleep over this trip. On the night prior to the occurrence the first officer obtained more than 8 hours of sleep and was feeling well rested.

Recent duty

The captain and first officer were based in Sydney and were rostered for a series of flights involving multiple duty periods. On 4 March 2013, they flew from Brisbane to Perth, arriving about 1930 WST. After a rest period of about 15 hours, they flew Perth to Singapore on 5 March, arriving at 1730 WST. After a rest period of 24 hours, they flew from Singapore to Perth, arriving about 0100 WST on 7 March.

Relevant aircraft systems

Auto-flight

The A330 is equipped with an auto-flight system that controls the aircraft's flight path according to the flight guidance mode engaged by the flight crew. The 'managed' mode guides the aircraft along pre-programmed route, vertical and speed profiles. In addition, there are two 'selected' vertical modes that guide the aircraft in response to flight path parameters selected by the crew during descent. These are open descent and vertical speed. Selected guidance always has priority over managed guidance.

The descent phase can be conducted in either managed or selected modes. In managed mode, the aircraft will be guided along a pre-computed descent profile determined by a number of factors such as altitude constraints, wind and descent speed. If the aircraft is above the computed profile, the speed will increase towards the upper limit of the speed range while maintaining engine thrust at idle. To increase the rate of descent while maintaining a target speed, flight crew should use a selected airspeed (entered in the flight control unit (FCU)) in combination with speed brake.

In either of the two selected vertical modes the aircraft descends to the altitude selected by the crew in the FCU, irrespective of any pre-programmed altitude constraints. In open descent mode, engine thrust is idle and generally results in high rates of descent. In vertical speed mode the aircraft will adopt a pitch attitude to achieve the vertical speed selected in the FCU with engine thrust varying to achieve the target airspeed.

For a descent in any of the modes, the flight management computers calculate the optimum descent profile and any subsequent deviation from that profile. The aircraft's position relative to the computed profile is indicated on the multifunction control display unit and, when the instrument landing system (ILS) is not active, is also indicated on the primary flight display. In addition, the predicted path intercept point (assuming half speed brake extension) is indicated on the navigation display. During descent the crew can also access information about the aircraft's flight path angle from the multifunction display.

ILS display

The A330 is equipped to receive and process the radio signals transmitted from a ground-based ILS facility. When these signals are available, the position of the aircraft relative to a lateral path (localiser) and vertical path (glide slope) to the runway are represented by symbols on deviation scales on each primary flight display (Figure 3).

Once the approach phase is activated, or the landing system button pushed, localiser and glide slope scales are displayed on each primary flight display. Deviation from computed profile is no longer displayed. ILS deviation symbols appear once signals are being received; however, it is possible for invalid glide slope indications to be presented on the primary flight display when the aircraft is outside of the defined coverage area.

Figure 3: A330 primary flight display with the glide slope indication scale highlighted in red

Source: Qantas

Enhanced ground proximity warning system

The A330 is equipped with an enhanced ground proximity warning system (EGPWS). The EGPWS uses aircraft inputs with onboard terrain, obstacle, and airport runway databases to predict potential conflicts between the aircraft's flight path and terrain or an obstacle.

When the EGPWS detects a conflict ahead of the aircraft, the conflict area is shown in solid yellow or red on the navigation display. The EGPWS includes aural warnings for excessive rates of descent, excessive rates of terrain closure, and of unsafe terrain clearance when not in the landing configuration.

Air traffic control procedures

Air traffic controllers are able to issue clearances for visual approaches when flight crew have established and can continue flight to the airport with continuous visual reference to the ground or water and with visibility at least 5 km. Once an air traffic controller clears a crew to conduct a visual approach, the crew has responsibility to maintain separation from terrain and, in the case of the occurrence flight, remain at least 500 ft above the lower limit of controlled airspace.

After the occurrence, the air traffic service provider (Airservices Australia) advised that the minimum safe altitude warning system (MSAW) had been inhibited in certain areas to the north-east of Melbourne to reduce the number of false alarms in those areas. In addition, Airservices Australia advised that when a flight is cleared for a visual approach its corresponding cleared flight level is set to 000 (ft) on the controller's air situation display. As a result, the system automatically inhibits the MSAW aural alarm and display for that flight.

Qantas procedures

Visual approach procedures

Qantas recommended its crews fly a continuous descent to touchdown at a nominal 3° profile when conducting a visual approach. While there may be slight variances, once the approach phase has been activated and the aircraft slowed (in this case, to a target speed of 180 kt), such a profile would generally approximate the flight profile generated by the flight management computers.

The only restriction on the use of open descent mode was that it was not to be used for final approach. Pilots were cautioned that open descent mode was not limited by altitude constraints, with the exception of the altitude target set in the FCU.

The procedures did not provide guidance on what altitude should be set in the FCU during a visual approach not involving a circuit. The captain later reported that the usual practice was to set a safe altitude as a limitation. The guidance regarding visual circuits did not include any reference to setting an altitude target in the FCU in case of a visual circuit, such as the 1,000 ft set by the captain in this case.

In addition, the procedures specified that during visual procedures both pilots were 'head free'. This allowed pilots to monitor external references as well as instruments, placing increasing emphasis on external visual cues as the aircraft progressed down the approach path. Qantas highlighted the importance of flight crew members being continuously aware of the intent of the pilot flying and the procedure nominated, and monitor that the aircraft was being operated in accordance with that procedure. If a procedure was not being adhered to or the aircraft deviated from the intended flight path, the pilot not flying was advised to immediately advise the pilot flying.

Maximum rates of descent

Maximum permitted descent rates were specified for operating the aircraft between 5,000 ft and 1,000 ft above ground level (AGL), such that the rate of descent was not greater than the aircraft's height above terrain. For example, when passing 2,000 ft, the rate of descent was limited to

2,000 ft/min. If excessive rates of descent were detected, the pilot not flying was required to call ‘Rate of Descent’ and the pilot flying acknowledge and adjust accordingly. The reduction to the permitted descent rate as the aircraft’s height reduced was to ensure increased recognition and response times in the event of an unintentional conflict with terrain. In this case, when the aircraft was descending below 2,000 ft AGL, the rate of descent was generally higher than that permitted. During the descent through 1,000 ft AGL the rate of descent was 1,900 ft/min.

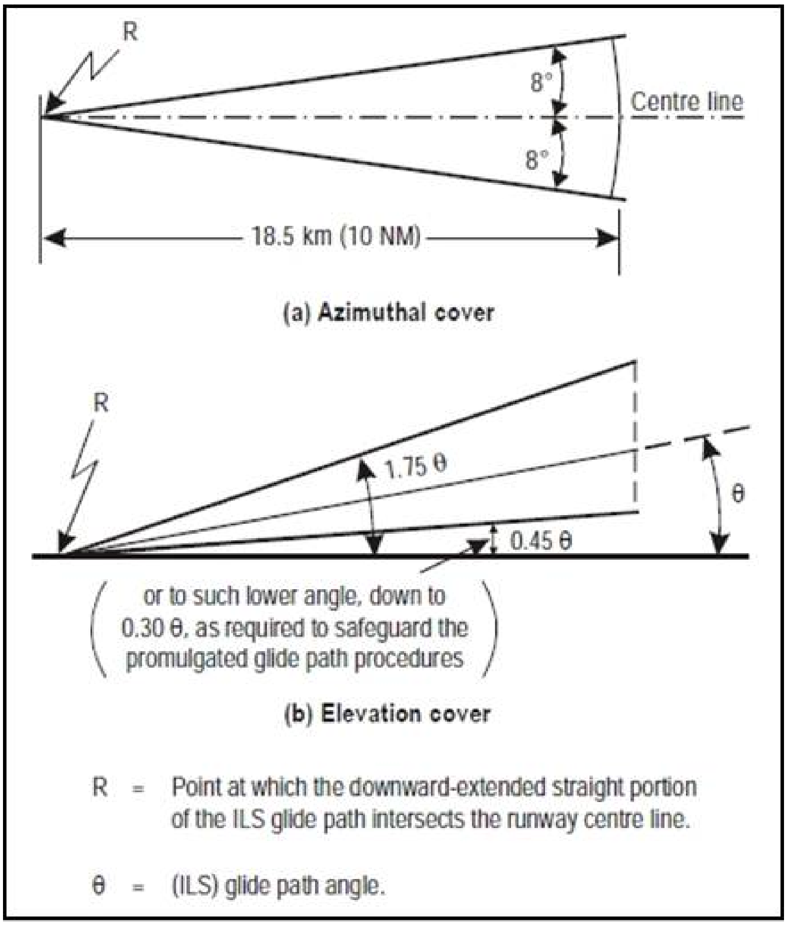
EGPWS procedures

The procedure relating to activation of the EGPWS ‘PULL UP’ warning required the crew to simultaneously disconnect the auto-flight system, pitch the aircraft up to the full back stick position and select take-off/go-around thrust, confirm speed brake retraction and adopt a wings-level attitude. For operations during daylight visual conditions, with terrain and obstacles clearly in sight, the alert could be considered cautionary; however, positive action was to be taken until the alert stopped or a safe flight path was assured. The crew’s actions in response to the warnings generated were consistent with the procedures.

Use of the ILS

The use of ILS glide slope indications when an aircraft was displaced from the approach centre-line was not specifically addressed in the Qantas procedures. However, a note in the standard operating procedures for conducting an ILS approach highlighted the International Civil Aviation Organization (ICAO)-defined envelope where the quality of the glide slope signal ensured a normal capture. This envelope was within 10 NM (18.5 km) and 8° either side of the glide path centre-line, and within a small range of elevation (Figure 4 – diagram not included in the Qantas procedures). The note indicated that when arming the approach well outside of the normal glide slope capture envelope, a spurious glide slope engagement may occur due to a wrong glide slope deviation signal. Whenever a pilot noticed any spurious indications, it was stipulated that the auto-flight system and approach mode be disengaged and recommended that any subsequent rearming of the approach mode occur within the normal capture zone.

Figure 4: ILS glide slope coverage



Source: ICAO Annex 10

Internal review of visual approach procedures

A Qantas investigation of this occurrence identified that:

> Qantas Airlines provide limited guidance on how a visual approach should be flown and the briefing required for the conduct of the approach to enable the Flight Crew to have a shared mental model.

That conclusion was consistent with the report from the first officer that there was no requirement for the visual approach brief to include detail of the intended auto-flight system mode selections.

Previous occurrences

A review of the ATSB occurrence database identified a number of other incidents where the aircraft was descended below the normal approach profile, resulting in the infringement of the minimum altitude requirements and, in some cases, activation of the EGPWS. These occurrences each involved the operation of the auto-flight system in open descent mode (or the equivalent 'flight level change' mode for occurrences involving Boeing aircraft), without an altitude target.

A number of ATSB investigations into those occurrences are summarised in the following discussion.[7]

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7 Available at www.atsb.gov.au.

ATSB investigation AO-2007-055

On 4 November 2007, a Boeing 777-2D7 (777) aircraft, registered HS-TJW, was being operated by Thai Airways International Ltd (Thai Airways) on a scheduled passenger service from Bangkok, Thailand to Melbourne, Victoria with 17 crew and 277 passengers on board. During the conduct of a non-directional beacon (NDB)[8] non-precision approach to runway 16 at Melbourne Airport in flight level change mode, the crew descended the aircraft below a segment minimum safe altitude. Soon after, the crew received two EGPWS cautions. At that time, the crew became visual with the ground below and the Melbourne aerodrome controller observed the aircraft 'unusually low for an aircraft'. The crew levelled the aircraft and made a visual approach and landed on runway 16.

The ATSB found that the aircraft descended below a critical altitude during the NDB approach and that the crew did not monitor the aircraft's progress correctly during the NDB approach.

Thai Airways had known about the difficulties in flying approaches without constant angle approach paths and was in the process of training flight crews on procedures specific to NDB approaches when the incident occurred. In October 2007, Thai Airways introduced a training program to instruct pilots on a new method to conduct those approaches. At the time of the incident, the pilots of the 777 had not undergone that training.

ATSB investigation AO-2010-027

On 4 and 29 May 2010, an Airbus A330-343E aircraft, registered 9M-XXB, was being operated by AirAsia X on scheduled passenger services from Kuala Lumpur, Malaysia to the Gold Coast, Queensland. On both occasions, there was low cloud and reduced visibility on arrival at the Gold Coast.

During non-precision instrument approaches conducted at Gold Coast Airport on both days, the flight crews descended the aircraft below the segment minimum safe altitudes and outside controlled airspace while using open descent mode. As a result, there was no longer separation assurance from terrain and aircraft operating outside controlled airspace.

While those operational non-compliances occurred prior to the final approach fix for the instrument approaches and not below 1,200 ft above aerodrome height, they were indicators of a minor safety issue regarding AirAsia X training of its flight crews.

In response to this incident, AirAsia X made a number of changes to flight crew procedures when conducting instrument approaches. In addition, the recurrent simulator training program was modified to include more complex non-precision instrument approaches.

ATSB investigation AO-2011-086

At 2019 Eastern Standard Time[9] on 24 July 2011, a Thai Airways Boeing 777-3D7 aircraft, registered HS-TKD, was conducting a runway 34 VOR[10] approach to Melbourne Airport, Victoria. During the approach, the tower controller observed that the aircraft was lower than required and asked the flight crew to check their altitude. The tower controller subsequently instructed the crew to conduct a go-around. However, while the crew did arrest the aircraft’s descent, there was a delay of about 50 seconds before they initiated the go-around and commenced a climb to the required altitude.

The ATSB established that the captain may not have fully understood some aspects of the aircraft’s automated flight control systems and probably experienced ‘automation surprise’ when the aircraft pitched up to capture the VOR approach path. As a result, the remainder of the

[8] A non-directional (radio) beacon (NDB) is a radio transmitter at a known location, used as a navigational aid. The signal transmitted does not include inherent directional information.

[9] Eastern Standard Time (EST) was Coordinated Universal Time (UTC) + 10 hours.

[10] A ground-based navigation aid that emits a signal that can be received by appropriately-equipped aircraft and represented as the aircraft’s bearing (called a 'radial') to or from that aid.

approach was conducted using the autopilot's flight level change mode. In that mode the aircraft's rate of descent is unrestricted and therefore may be significantly higher than that required for an instrument approach. In addition, the flight crew inadvertently selected a lower than stipulated descent altitude, resulting in descent below the specified segment minimum safe altitude for that stage of the approach and the approach not being managed in accordance with the prescribed procedure.

ATSB investigation AO-2012-103

On 16 July 2012 at about 0830 New Zealand Standard Time[11], an Airbus A320-232 aircraft, registered VH-VQA and operated by Jetstar Airways (Jetstar), was conducting an Area Navigation (Required Navigation Performance) approach to runway 05 at Queenstown, New Zealand. During the approach the aircraft descended below two segment minimum safe altitudes. Upon recognising the descent profile error, the crew climbed the aircraft to intercept the correct profile and continued the approach to land.

The ATSB found that, contrary to their intentions, the flight crew continued descent with the auto-flight system in open descent mode, which did not provide protection against infringing the instrument approach procedure's segment minimum safe altitudes. The ATSB also found that the flight crew was not strictly adhering to Jetstar's sterile flight deck procedures, which probably allowed them to become distracted.

The ATSB found that the Jetstar procedures did not specifically draw the flight crew's attention to unchanged auto-flight system modes during descent or prompt crew reconsideration of the most suitable descent mode at any point during descent. Additionally, the Jetstar's procedures allowed the crew to select the altitude to which they were cleared by air traffic control on the flight control unit altitude selector, irrespective of intervening altitude constraints. This combination of procedures provided limited protection against descent through segment minimum safe altitudes.

[11] New Zealand Standard Time (NZST) was Coordinated Universal Time (UTC) + 12 hours.

Safety analysis

Introduction

While the flight crew was conducting a visual approach and tracking to intercept final approach, the aircraft descended about 1,900 ft below the nominal 3° descent profile to about 600 ft above ground level (AGL), activating the aircraft's enhanced ground proximity warning system (EGPWS). Shortly before that alert, the crew had identified that the aircraft was low and were in the process of responding when the EGPWS activated. The crew conducted an EGPWS recovery manoeuvre followed by a routine instrument approach and landing. The following analysis will examine the factors that contributed to the abnormal descent, which led to the EGPWS warning, and review the risk controls as they apply to visual approaches.

Abnormal flight path

The significant descent below the intended flight path was consistent with degraded flight crew situation awareness for a period during the visual approach.

Situation awareness is a human perceptual state in which information is gained from the environment through a number of processes. These processes are believed to be the perception of environmental elements, the comprehension of their meaning and the projection of their status following a change in a variable (such as time) (Endsley, 2005). For a visual approach the available cues include visual reference to terrain, track distance to the next waypoint or touchdown, flight path vector on the primary flight display (deviation from the nominal approach path), multifunction control display unit profile indication and barometric and radio altimeter indications. In addition, within the specified coverage of the instrument landing system (ILS), the localiser and glide slope indications can be used.

After accepting track shortening, the captain assessed that the aircraft was above the re-computed profile. As a result the captain selected open descent mode and half speed brake to increase the descent rate. This resulted in a higher than normal descent rate and, by continuing in open descent mode, the aircraft's descent was only constrained by the altitude target selected in the flight control unit (FCU).

It was crucial, then, for the crew to maintain an increased awareness of the aircraft's flight path relative to the computed profile and controlled airspace restrictions. However, it appears that the crew did not maintain that awareness because the aircraft subsequently descended significantly below profile until the EGPWS warnings at 1851.

Both pilots were expected to monitor the flight path and ensure that the trajectory and energy of the aircraft, current and projected, conformed to the planned approach. The first officer, as pilot not flying, reported monitoring the flight path during the approach. It is not clear if the first officer noticed that the aircraft was below profile during the latter stages of the approach but the captain, who was the pilot flying, was not advised that the aircraft was 'low' until just before the EGPWS warning.

The captain observed that the ILS glide slope indications were active and indicating that the aircraft was above the glide slope, which was consistent with his expectation. As a result, the captain considered the glide slope indications to be valid and useful for flight path guidance. Subsequently, the captain focussed on the glide slope without any apparent reference to the other available flight path or profile information.

Glide slope indications outside of the specified coverage area were unreliable and therefore an invalid source of flight path guidance. In addition, even if the signal was valid, following a glide slope indication with more track miles to fly than the straight-line distance to the glideslope antenna would, with reference to the track miles to run, result in a shallower flight path than the nominal 3° profile. Reference by the crew to the other available cues during the visual approach would have increased the likelihood of them detecting that the aircraft was below profile.

When cleared for the visual approach, the captain set 1,000 ft in the FCU, which although permitted by the manufacturer and operator, was well below the altitude of about 2,200 ft required to intercept the final approach path at a nominal 3° profile. Although the reason for the FCU setting by the captain could not be determined, the effect was that, in the open descent mode, the aircraft would descend to within 550 ft AGL unless the crew intervened. Selection of a more appropriate altitude target would have provided an effective defence in the event of degraded situation awareness.

Although the aircraft was about 1,900 ft below profile on receipt of clearance for the visual approach, the descent was continued in a high drag configuration using open descent mode until the first officer announced that the aircraft was low. The captain then selected vertical speed mode to reduce the aircraft's rate of descent; however, this did not prevent activation of the EGPWS alerts and subsequent warning.

In summary, the flight crew's situation awareness during the visual approach was adversely affected by the captain's focus on the glide slope indication and the crew not recognising and communicating the deviation from the nominal descent profile until the aircraft was approaching about 1,300 ft AGL.

Fatigue and related factors

Fatigue can have a range of adverse influences on human performance, such as slowed reaction time, decreased work efficiency, reduced motivational drive, increased variability in work performance, and more lapses or errors of omission (Battelle Memorial Institute 1998). In addition, most people generally underestimate their level of fatigue.

Sleep is vital for recovery from fatigue, with both the quantity and quality of sleep being important. It is generally agreed that most people need at least 7 to 8 hours of sleep each day to achieve maximum levels of alertness and performance. Some research has concluded that less than 5 hours sleep in the previous 24 hours is inconsistent with a safe system of work (Dawson and McCullough 2005) whereas other research has shown that having less than 6 hours sleep affects performance (Thomas and Ferguson 2010, Williamson and others 2012).

The captain

The captain reported feeling tired on the morning of the occurrence and during the afternoon of the occurrence flight. He had 6 hours disrupted sleep the night before the occurrence, and his previous sleep, of about 6.5 hours, occurred outside his normal circadian low. Although time awake, time of day when the occurrence happened and workload did not appear noteworthy, the captain reported having a sore throat and cold symptoms during the day. There appeared to be no concerns regarding the length of the time between duty periods or the standard of accommodation.

The captain also reported having very little nutrition on the day of the occurrence, including no breakfast or lunch. Research has provided inconsistent results regarding the effects of missed meals on performance. However, Barshi and Feldman (2012) have recently concluded that low blood sugar due to a lack of food has a range of effects on cognitive performance, and the effects are often significantly underestimated (see also Feldman and Barshi 2007). It is also widely accepted that regular nutrition is an important fatigue countermeasure.

In summary, the captain was experiencing the effects of recent restricted and disrupted sleep, a cold/virus and limited nutrition. It is reasonable to conclude that the combination of these factors probably reduced the captain's capability to perform during the occurrence flight. However, it was difficult to establish the level of reduction or the extent to which it may have influenced the captain's actions during the occurrence, and there were no indications that the captain's performance was actually affected prior to the occurrence.

The first officer

In relation to the first officer, there were no indicators of fatigue and the late communication of the descent profile deviation may have been associated with the general human factors limitations that counter effective flight path monitoring. These limitations are discussed in the following section.

Flight path monitoring

As this and other occurrences have shown, flight path monitoring is subject to a number of challenges or barriers related to human factors limitations and has recently been the focus of several industry working groups and related research. The findings from these working groups and studies highlight the various human performance limitations that are detrimental to effective monitoring.

Dismukes and Berman (2010) showed that although checklists and flight crew monitoring are important defences, and in the vast majority of cases are performed appropriately, they do not always catch flight crew errors and equipment malfunctions. They also noted:

> …even though automation has enhanced situation awareness in some ways, such as navigation displays, it has undercut situation awareness by moving pilots from direct, continuous control of the aircraft to managing and monitoring systems, a role for which pilots are poorly suited. Also, the very reliability of automation makes it difficult for pilots to force themselves to "stay in the loop". Research is needed to develop ways to help pilots stay in the loop on system status, aircraft configuration, flight path, and energy state. These new designs must be intuitive and elicit attention as needed, but minimize effortful processing that competes with the many other attentional demands of managing the flight.

The United States Flight Safety Foundation (FSF) Active Pilot Monitoring Working Group has developed a practical guide to improving flight path monitoring (Flight Safety Foundation, 2014). The guide listed four general human factors limitations that adversely affect monitoring:

- The human brain has difficulty with sustained vigilance
- The human brain has quite limited ability to multitask
- Humans are vulnerable to interruptions and distractions
- Humans are vulnerable to cognitive limitations that affect what they notice and do not notice.

A number of other factors were identified that could inhibit effective flight path monitoring. These included time pressure, lack of feedback to pilots when their monitoring lapses, the design of flight deck systems and procedures, inadequate mental models of auto-flight system modes and a lack of organisational emphasis and practical guidance on monitoring.

The Dismukes and Berman study also examined monitoring deviations and found those relating to 'not monitoring aircraft state or position' were the least frequent, at 17 per cent. The most common type was a late or omitted call (such as '1,000 [ft] to go'), followed by omitted verification of system status. Of interest to this occurrence, the authors found that 'some deviations are clearly unintentional, such as deviations from flight path'. The authors went on to state that 'given the large numbers of opportunities for deviation, the deviation rates were probably well below one percent' and '…the vast majority of deviations had no observable outcome'.

The United Kingdom Civil Aviation Authority (CAA) formed a Loss of Control Action Group to examine and provide guidance on, among other things, the development of pilot monitoring skills. The resulting guidance emphasised the importance of 'a structured and interactive briefing' which '…provides the crew with an opportunity to: share a common action plan; and set priorities and share tasks…' including the need to 'brief the plan for energy management with altitudes and minimum approach gates'.

The FSF working group, the CAA action group and the study by Dismukes and Berman (details of which are available in the section titled *Sources and submissions)* each made a number of recommendations and suggestions in the areas of monitoring practices, policy and procedures, auto-flight system monitoring and training and evaluating monitoring skills. Pilots and operators may benefit from a review of this advice.

The ATSB did not identify any specific factors that adversely affected the first officer's ability to monitor the flight path. However, it is likely that the first officer was not expecting or aware of the captain's use of the ILS glide slope information as the primary reference for flight path guidance. In addition, the first officer did not recall hearing the captain verbalise the selection of 1,000 ft in the FCU. While the first officer should have been able to independently monitor the approach using other valid information, it was apparent that the crew did not have a shared mental model of how the approach would be flown. The absence of a shared mental model increased the risk that the first officer would not identify and respond appropriately to the captain's actions. It is also possible that the general limitations of human monitoring capability discussed above may have influenced the first officer's performance.

Approach procedures

This occurrence demonstrates the risks associated with using ILS glide slope indications for primary navigation reference outside of the specified coverage area. Integration of other available external and internal cues enhances situation awareness and reduces those risks.

The crew's selection of auto-flight open descent mode during the latter stages of the approach, combined with the high-drag configuration, generated a high rate of descent close to the ground without altitude constraints or an effective FCU altitude target. Although Qantas allowed the use of open descent mode during visual approaches, this selection increased the risk of high rates of descent and inadvertent descent below minimum altitude requirements.

One of the risk controls that can be used during an approach is to set an FCU target altitude that provides assurance that the aircraft's descent path is appropriately constrained. Had the crew set 2,200 ft as the target altitude in the FCU for arrival overhead the final approach fix, the aircraft's auto-flight system would have captured that altitude prior to the fix and provided an opportunity for the crew to recognise that the aircraft was below the nominal descent profile.

Operators may benefit from considering the adequacy of their guidance on how FCU target altitude selections should be used during visual approaches. Such guidance would reduce the risk of inadvertent descent below the intended flight path.

Findings

From the evidence available, the following findings are made with respect to the flight path management and ground proximity warning involving Airbus A330, registered VH-EBV and operated by Qantas Airways Limited (Qantas), that occurred 15 km north-east of Melbourne Airport, Victoria on 8 March 2013. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance. A safety issue is an event or condition that increases safety risk and (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

Contributing factors

- During the latter stages of a visual approach the captain assessed the aircraft's flight path using glide slope indications that were not valid, resulting in an incorrect assessment that the aircraft was above the nominal descent profile.
- The combination of the selection of an ineffective altitude target while using the auto-flight open descent mode and ineffective monitoring of the aircraft's flight path resulted in a significant deviation below the nominal descent profile.
- The flight crew's action to reduce the aircraft's rate of descent following detection of the altitude deviation did not prevent the aircraft descending outside controlled airspace and the activation of the enhanced ground proximity warning system.

Other factors that increased risk

- **Qantas provided limited guidance on the conduct of a visual approach and the associated briefing required to enable the flight crew to have a shared understanding of the intended approach. [Safety issue]**
- The captain's performance capability was probably reduced due to the combined effects of disrupted and restricted sleep, limited recent nutrition and a cold/virus.

Other findings

- The flight crew acted to reduce the aircraft's rate of descent prior to the activation of the enhanced ground proximity warning system (EGPWS) and conducted a recovery manoeuvre immediately after the EGPWS 'PULL UP' warning.

Safety issues and actions

The safety issue identified during this investigation is listed in the *Findings* and *Safety issues and actions* sections of this report. The ATSB expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Visual approach guidance

Number:	AO-2013-047-SI-01
Issue owner:	Qantas Airways Limited (Qantas)
Operation affected:	Aviation: Air transport
Who it affects:	Flight crew

Safety issue description:

Qantas provided limited guidance on the conduct of a visual approach and the associated briefing required to enable the flight crew to have a shared understanding of the intended approach.

Proactive safety action taken by Qantas

Action number: AO-2013-047-NSA-032

Qantas advised that in response to this occurrence they:

Updated the material for visual approaches in their flight training library.

Enhanced the material for visual approaches in the captain and first officer conversion/promotion training books including targeted questions that required check pilot sign off for proficiency.

Added visual approaches as a subject for discussion during flight crew route checks for 2013/2014 and 2015.

Current status of the safety issue:

Issue status: Adequately addressed

Justification: The ATSB is satisfied that the safety action adequately addresses this safety issue.

General details

Occurrence details

Date and time:	8 March 2013 – 1851 EDT	
Occurrence category:	Serious incident	
Primary occurrence type:	Enhanced ground proximity warning system alert	
Location:	15 km north-north-east of Melbourne Airport, Victoria	
	Latitude: S 37° 32.28'	Longitude: E 144° 53.37'

Pilot details – Captain

Licence details:	Airline Transport Pilot (Aeroplane) Licence
Medical certificate:	Class 1, valid to June 2013
Aeronautical experience:	Approximately 21,900 hours
Experience on type - A330:	Approximately 2,270 hours
Last flight review:	February 2013

Pilot details – First Officer

Licence details:	Airline Transport Pilot (Aeroplane) Licence
Medical certificate:	Class 1, valid to May 2013
Aeronautical experience:	Approximately 10,030 hours
Experience on type - A330:	Approximately 1,000 hours
Last flight review:	January 2013

Aircraft details

Manufacturer and model:	Airbus A330	
Registration:	VH-EBV	
Operator:	Qantas Airways Limited	
Serial number:	1365	
Type of operation:	Air Transport High Capacity	
Persons on board:	Crew – 11	Passengers – 211

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- flight crew and operator of VH-EBV
- aircraft flight data recorder
- aircraft manufacturer
- Airservices Australia (Airservices).

References

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Dawson, D & McCulloch, K 2005, 'Managing fatigue: It's about sleep', *Sleep Medicine Reviews*, vol. 9, pp. 365-380.

Dismukes, RK & Berman, B 2010, *Checklists and monitoring in the cockpit: Why crucial defences sometime fail,* National Aeronautics and Space Administration Technical Memorandum NASA/TM-2010-216396.

Endsley, M. R. 1995. 'Toward a theory of situation awareness in dynamic systems.' *Human Factors,* vol. 37(1), pp 32-64.Feldman, J & Barshi, I 2007, *The effects of blood glucose levels on cognitive performance: A review of the literature*, NASA Technical Memorandum TM-2007-214555.

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United Kingdom Civil Aviation Authority 2013, *Monitoring Matters: Guidance on the Development of Pilot Monitoring Skills,* CAA Paper 2013/02.

Williamson, A Lombardi, Folkard DA, Stutts, S. Courtney, J. T.K. & Connor, J.L. 2011, 'The link between fatigue and safety', *Accident Analysis and Prevention*, vol. 43, pp. 498-515.

Submissions

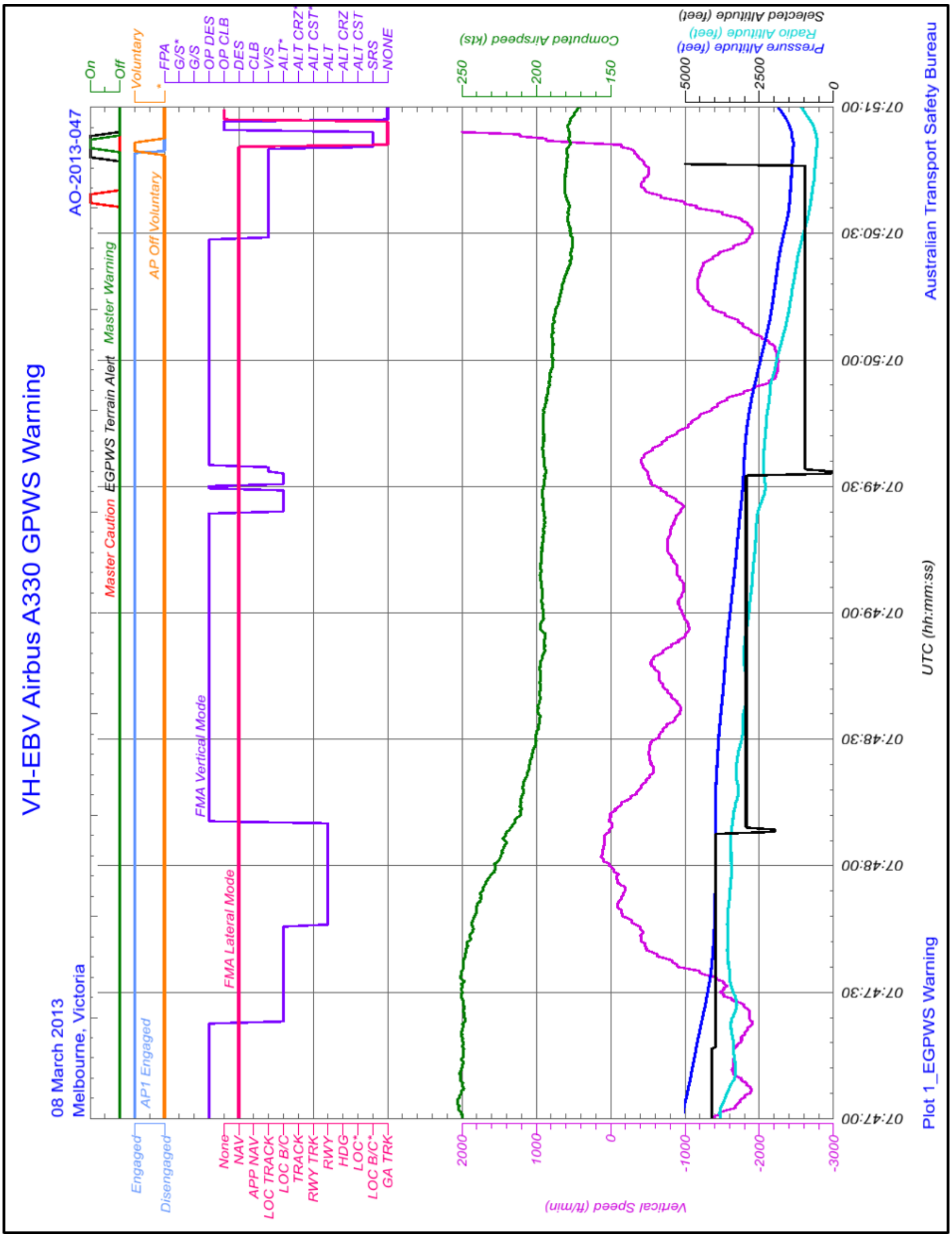
Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the flight crew and operator of VH-EBV, the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA), the aircraft manufacturer, Airservices and the Civil Aviation Safety Authority.

Submissions were received from the flight crew and operator of VH-EBV, the BEA, the aircraft manufacturer, Airservices and the Civil Aviation Safety Authority. The submissions were reviewed and where considered appropriate, the text of the draft report was amended accordingly.

Appendices

Appendix A –VH-EBV flight data recorder and enhanced ground proximity cautions, alerts and warnings



Australian Transport Safety Bureau

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation

Flight path management and ground proximity warning involving Airbus A330-202, VH-EBV, 15 km NNE of Melbourne Airport, Victoria
8 March 2013

AO-2013-047
Final – 9 July 2015